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# Effects of selenium fertilizer application rates on the yield, quality, and selenium content of different rice varieties grown in selenium-rich soils*

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## Abstract

Guangxi boasts extensive selenium-rich soils, creating favorable conditions for screening high-quality rice varieties that can be cultivated in this region and determining the optimal selenium fertilizer spraying concentrations for their growth. In this study, three major rice varieties predominantly grown in the area were selected for evaluation (Ge68 Superior 9938, Guiyu 9 and Yexiang Youlisi). A clear water control (CK), Treatment 1 (T1, with the application of 100 g•hm$^{-2}$ amino acid-based organic selenium), and Treatment 2 (T2, with the application of 200 g•hm$^{-2}$ amino acid-based organic selenium) were established. Rice yield, brown rice percentage, selenium content in different plant parts, and the levels of certain rice quality indicators were measured. Additionally, the entropy weight-TOPSIS method was employed to evaluate the comprehensive performance of the eight indicators under different treatments. Results indicate that foliar application of selenium (Se) fertilizer significantly increased rice yield by over 8.7% compared to the control group (CK), but had no significant effect on brown rice rate. Under selenium treatment, selenium content in stems, leaves, panicle stems, and grains of all three rice varieties significantly exceeded the control group, with maximum increases of 0.33, 1.12, 0.38, and 0.26 mg/kg, respectively. Regarding nutritional quality, treatment 2 (T2) significantly elevated protein, amylose, lipid, and amino acid content across all three rice varieties. Entropy-weighted TOPSIS analysis indicated that for the rice variety YexiangYouLisi cultivated in Guangxi's selenium-enriched region, foliar application of selenium fertilizer at a concentration of 200 g•hm-2 was optimal. This concentration not only yielded the highest grain yield and grain quality for this variety but also maintained selenium levels in stems, leaves, panicle stems, and grains within suitable ranges.

## Keywords

Cultivar, selenium-rich soil, TOPSIS, yield and quality

## Introduction

Selenium is an essential trace nutrient for the human body, possessing multiple functions including immune regulation, reproductive enhancement, detoxification, anti-aging, and cancer prevention. Selenium deficiency in humans can lead to diseases such as Keshan disease, white muscle disease, and osteochondrodysplasia (Li et al. 2012; Hatfield et al. 2014).

Dinh et al. (2018) research indicates that 36% to 61% of Chinese residents suffer from severe daily selenium deficiency. Consuming selenium-enriched agricultural products is widely recognized as a safe and effective solution. Currently, China's selenium-enriched products have developed into a diverse range of categories, with agricultural products such as selenium-enriched rice and tea occupying a dominant position (Huang et al. 2025). Exogenous application of selenium fertilizers can increase selenium

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content in crops. The primary methods of selenium fertilizer application include seed dressing, soil incorporation, and foliar spraying (Peng et al. 2017). Guangxi possesses uniquely favorable natural conditions for cultivating high-quality selenium-enriched rice. However, its vast geographical span and uneven distribution of arable land mean that different regions are suited to distinct varieties of selenium-enriched rice. The lack of precise data on selenium-enriched rice makes it difficult to support the selection, cultivation, and promotion of these varieties. This situation prevents the unique nutritional value and market potential of Guangxi's selenium-enriched rice from translating into tangible economic benefits, thereby constraining the diversification and high-quality development of the regional agricultural economy (Li et al. 2021).

Research on the optimal application rates of exogenous selenium for selenium-enriched rice in Guangxi remains limited. To efficiently utilize selenium-rich soil resources, explore fertilization concentrations suitable for Guangxi's selenium-enriched soils, maximize selenium content in rice grains, and expand selenium-enriched agricultural data for rice varieties in Guangxi, this study utilized three major rice varieties cultivated in Guangxi: Yexiang Youlisi, Ge 68 Superior 9938, and Guiyu 9. Through foliar application of selenium fertilizer, the study analyzed the effects of exogenous selenium on grain selenium content, yield, and quality across these varieties. A comprehensive evaluation using the Entropy Weighted TOPSIS method was conducted based on eight indicators: grain selenium content, yield, brown rice rate, amylose content, lipid content, protein content, total essential amino acids, and selenium fertilizer cost. This study aims to identify the most suitable rice varieties and selenium fertilizer application rates for cultivation in southern Guangxi, providing a reference for selenium-enriched rice production in the region.

# Materials and methods

## Test materials

The rice varieties tested were Yexiang YouLisi, provided by Guangxi Lvhai Seed Co., Ltd.; Ge 68 Superior 9938, provided by Chongzuo Agricultural Science Research Institute; and Guiyu 9, provided by the Rice Research Institute, Guangxi Academy of Agricultural Sciences. The amino acid-based organic selenium formulation used in the trial (organic selenium content ≥ 2 g•$L^{-1}$) was provided by the Agricultural Resources and Environment Resources Institute, Guangxi Academy of Agricultural Sciences.

## Test method

### *Overview of the Pilot Zone*

The experiment commenced in March 2021 at Busong Village, Jiangzhou Town, Jiangzhou District, Chongzuo City, Guangxi Zhuang Autonomous Region (22°9'34"N, 107°27'30"E). The site features a favorable ecological environment with sandy loam soil. Prior to the experiment, basic physicochemical properties of the soil were determined: total nitrogen1.6 g•$kg^{-1}$, total phosphorus1.2 g•$kg^{-1}$, total potassium 12.4 g•$kg^{-1}$, organic matter 25.80 g•$kg^{-1}$, pH 5.75, and total selenium0.4 mg•$kg^{-1}$. These values meet the criteria for selenium-enriched soil.

### *Planting*

Seeding was conducted on March 20. Rice seedlings were transplanted on April 10 (at the 4-leaf stage). Maintaining a spacing of 20 cm × 25 cm between plants and rows. Water and fertilizer application, weed control, and pest management followed standard field practices. Each treatment plot covered 20 $m^2$, with three replicates per treatment, totaling 27 plots.

Spray concentrations: 0 g•$hm^{-2}$, 100 g•$hm^{-2}$, and 200 g•$hm^{-2}$.

Application timing: Spraying was conducted on rice leaves before sunrise during the heading stage, ensuring leaf surface wetness for 30 minutes. Each plot received 1 kg of spray solution.

### *Sample collection and analysis*

On July 3, a unified harvest was conducted by cutting the entire aboveground portion of each rice plant. Rice from each experimental field was bagged separately for yield calculation.

In the laboratory, rice stems and leaves were washed successively with tap water and deionized water. They were then placed separately in an oven, blanched at 105 °C for 30 min, dried at 65 °C to constant weight, and finally ground for determining selenium content in different rice tissues. After sun-drying the rice panicles, the grains were threshed and weighed. The hulled rice grains were milled into rice flour, sieved through a 0.15 mm mesh, and used for quality analysis. For testing, samples free of pests and diseases and devoid of impurities were selected. Each sample underwent three replicate measurements for all indicators.

The brown rice rate is determined using the constant method specified in "Methods for Determining Rice Quality"(NY/T 83-2017). After dehulling the rice, weigh 140 g (m) of the rice grain sample, and subjected to secondary dehulling in the machine. Residual grains in the brown rice were then removed. The mass of brown rice ($m_2$) and the mass of residual grains ($m_1$) were weighed separately and calculated using the following formula, brown rice rate = $m_2/(m\text{-}m_1) \times 100$.

Determination of selenium content in brown rice: conducted in accordance with the national standard"National Food Safety Standard: Determination of Selenium in Foods"(GB 5009.93-2017) using the hydride atomic fluorescence spectroscopy method. This involves wet digestion with a mixed acid solution of $HNO_3$+$HClO_4$, followed by determination of selenium content in the solution using a hydride generation-atomic fluorescence photometer.

The content of amylose in rice shall be determined in accordance with"Testing of Grain and Oil Products—Determination of Amylose Content in Rice"(GB/T 15683—2025). Weigh 0.1 g of ground rice into a beaker, add 1 ml of anhydrous ethanol, and slowly add 9.0 ml of 1.0 mol/L sodium hydroxide solution while stirring thoroughly. Place the beaker in boiling water for 10 minutes, then cool to room temperature. Take the supernatant as the test solution. Simultaneously prepare a blank solution (substituting 5 ml of 0.09 mol/L sodium hydroxide solution for the sample, with all other steps identical). Transfer 5 ml of the test solution to a volumetric flask containing 50 ml water. Add 1 ml acetic acid, followed by 2 ml iodine reagent. Dilute to 100 ml with water, mix thoroughly, and allow to stand for 10 minutes. Pipette the sample into a cuvette. Using the blank solution as reference, measure the absorbance of the test solution at 720 nm wavelength.

Lipid content is determined according to "National Food Safety Standard: Determination of Lipid in Foods" (GB 5009.6—2025). Weigh 5 g of dried sample and transfer it into a dry filter paper cylinder. Place the filter paper cylinder into the extraction flask of the Soxhlet extractor and connect it to a receiving flask dried to constant weight. Add anhydrous diethyl ether from the top of the extractor's condenser until it reaches two-thirds of the receiving flask's volume. Heat in a water bath at 50–60 °C, allowing the solvent to reflux at a rate of 6 to 8 times per hour for 6–10 h. Dip a ground glass rod into 1 drop of the extract. If no oil spot appears on the rod, extraction is complete. Recover the anhydrous ether. When 1–2 ml of solvent remains in the receiving flask, evaporate to dryness in a 60 °C water bath. Subsequently, place the receiving flask in an oven at 100 °C for 1 h to dry, then cool to room temperature and weigh. Repeat the procedure until constant weight is achieved.

Protein content was determined using the Kjeldahl method per"National Food Safety Standard: Determination of Protein in Foods"(GB 5009.5—2025). Weigh 2 g of sample, add 0.4 g copper sulfate, 6 g potassium nitrate, and 20 ml sulfuric acid into the digestion furnace. Maintain at 420 °C for 1 h. Finally, the total nitrogen content is measured by instrument and converted to protein content: Protein content (%) = total nitrogen content (%)×nitrogen conversion factor (5.95). The instrument used is the K9860 fully automatic Kjeldahl nitrogen analyzer.

Amino acid content determination: Weigh 0.3 g of sample into a 50 ml centrifuge tube. Add 25 ml of 0.2% formic acid aqueous solution. Vortex for 6 minutes. sonicate for 40 min. Transfer the supernatant to a 2 ml centrifuge tube, centrifuge at 4 °C and 12,500 rpm for 10 min. Transfer the supernatant, filter through a 0.22 μm membrane, and analyze using an EXPEC5210 triple quadrupole liquid chromatography-mass spectrometry (LC-MS) system.

### *Data processing and analysis*

The Entropy Weighted TOPSIS method was employed to comprehensively evaluate eight indicators and selenium fertilizer costs across three rice varieties under various selenium fertilizer treatments. Currently marketed amino acid-organic chelated selenium fertilizers cost 15 CNY•$g^{-1}$ of pure selenium. Thus, the selenium fertilizer cost for T1 treatment was 1500 CNY•$hm^{-2}$, and for T2 treatment, 3000 CNY•$hm^{-2}$. The Entropy Weighted TOPSIS calculations were performed using SPSSAU software. Data processing, statistical analysis, and graphing were performed using MS Excel 2020, IBM SPSS 27, and SPSS software.

## Results

### Effect of selenium fertilizer application on rice yield

The effects of selenium treatment on rice yield are shown in Fig. 1. Under the T1 treatment, the yields of Guiyu 9, Ge 68 Superior 9938, and YexiangYouLisi were 7.61 t•$hm^{-2}$, The effects of selenium treatment on rice yield are shown in Fig. 1. Under treatment T1, the yields of Guiyu 9, Ge 68 Superior 9938, and Yexiang YouLisi were 7.61 t•$hm^{-2}$, 7.61 t•$hm^{-2}$, and 7.21 t•$hm^{-2}$, respectively, all significantly higher than the CK (control), with increases of 23.6%, 22.7%, and 8.7%. These results indicate that selenium fertilizer application significantly enhances rice yield.

### Effects of selenium fertilizer spraying on selenium content in different parts of rice plants

Fig. 2 data indicate that compared to CK, T1 treatment significantly increased selenium content in stems, leaves, panicle stems, and grains across three rice varieties. Specifically, selenium content in stems of Guiyu 9, Ge 68 Superior 9938, and YexiangYouLisi increased by 0.33 mg•$kg^{-1}$, 0.65 mg•$kg^{-1}$, and 0.09 mg•$kg^{-1}$ respectively compared to CK; leaf selenium content increased by 0.40 mg•$kg^{-1}$, 1.05 mg•$kg^{-1}$, and 0.20 mg•$kg^{-1}$, respectively; panicle stalk selenium content increased by 0.16 mg•$kg^{-1}$, 0.26 mg•$kg^{-1}$, and 0.03 mg•$kg^{-1}$, respectively; Selenium content in grains increased by 0.21 mg·$kg^{-1}$, 0.26 mg·$kg^{-1}$, and 0.08 mg·$kg^{-1}$, respectively.

Under T2 treatment conditions, selenium content in stems, leaves, panicle stems, and grains of all three rice varieties was significantly higher than CK. Specifically, the stem selenium content of Guiyu 9, Ge 68 Superior 9938, and YexiangYouLisi increased by 0.59 mg·$kg^{-1}$, 0.58 mg·$kg^{-1}$, and 0.30 mg·$kg^{-1}$ respectively compared to CK; Leaf selenium content increased by 1.15 mg·$kg^{-1}$, 0.12 mg·$kg^{-1}$, and 0.08 mg·$kg^{-1}$ compared to CK, respectively; Selenium content in the ear stalk increased by 0.27 mg·$kg^{-1}$, 0.37 mg·$kg^{-1}$, and 0.07 mg·$kg^{-1}$ compared to CK, respectively; Grain selenium content increased by 0.25 mg·$kg^{-1}$, 0.17 mg·$kg^{-1}$, and 0.05 mg·$kg^{-1}$ compared to CK, respectively.

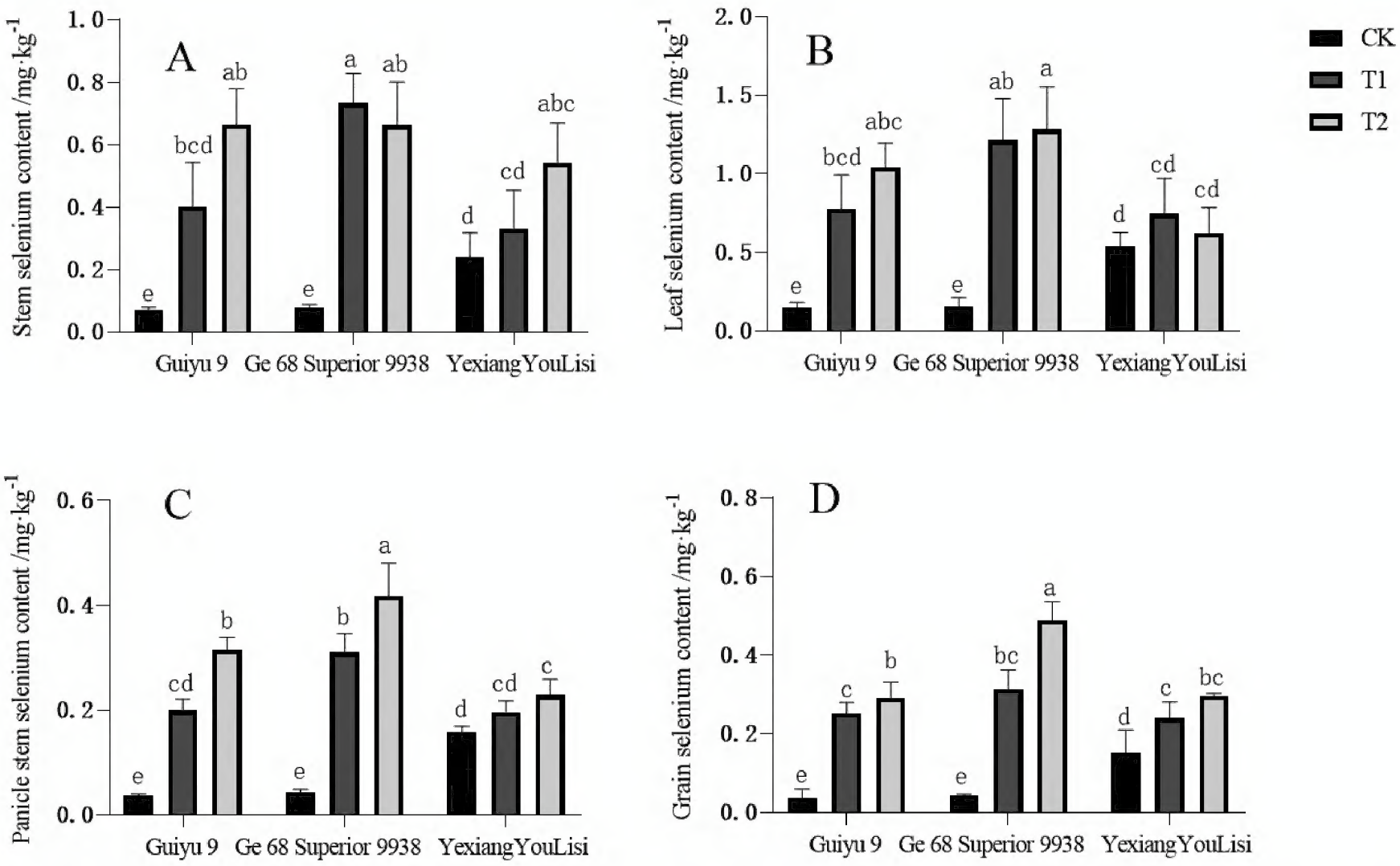


**Figure 1.** Rice yield under different selenium treatments. Note: Different lowercase letters indicate significant differences among selenium treatments at $p < 0.05$.

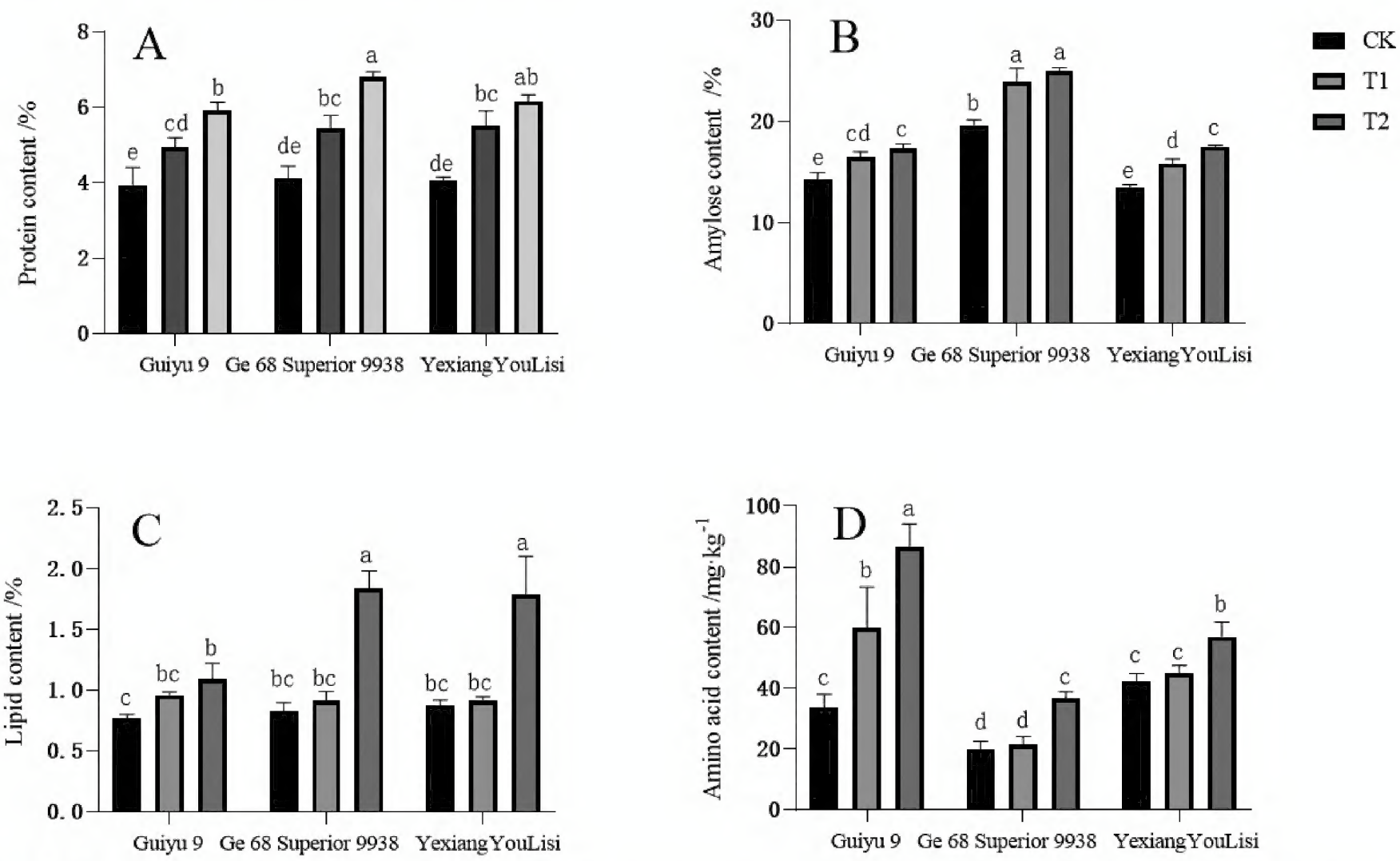


**Figure 2.** Selenium content in different parts of rice under different selenium treatments. Note: Different lowercase letters indicate significant differences among selenium treatments at $p < 0.05$.

## Effect of selenium fertilizer application on brown rice yield in rice

The results are shown in Fig. 3 Under T1 treatment, the average brown rice rates for Guiyu 9, Ge 68 Superior 9938, and Yexiang YouLisi were 71.36%, 79.19%, and 77.96%, respectively. while under treatment T2, the average brown rice rates for Guiyu 9, Ge 68 Superior 9938, and Yexiang You Lisi were 70.89%, 78.82%, and 77.11%, respectively. According to the quality standards in"Paddy"(GB 1350-2009), the brown rice rates of Ge 68 Superior 9938 and Yexiang YouLisi under selenium treatment both met the Grade II brown rice standard (≥77%). However, the brown rice rate of Guiyu 9 under selenium treatment failed to reach

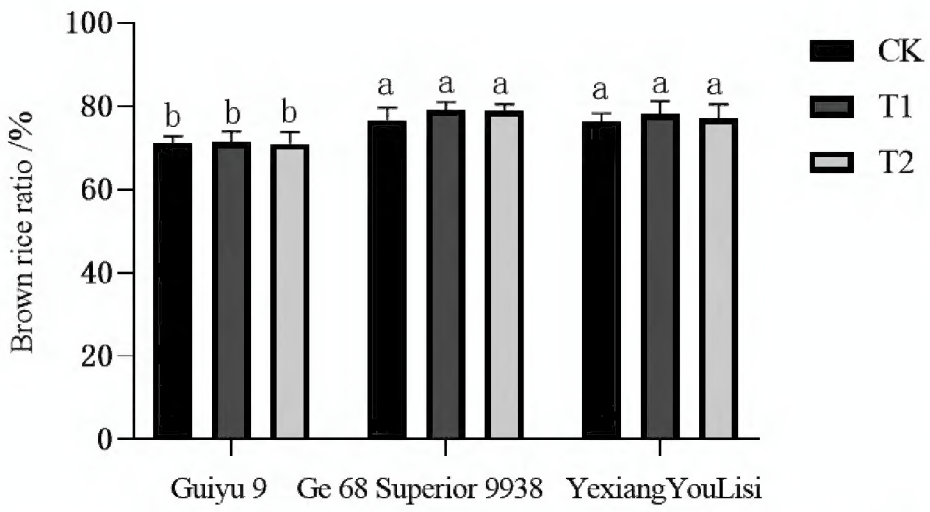


**Figure 3.** Brown rice rate of rice under different selenium treatments. Note: Different lowercase letters indicate significant differences among selenium treatments at $p < 0.05$.

the minimum Grade IV brown rice standard (≥73%). This indicates that the brown rice rates of all three rice varieties under selenium fertilizer treatments (T1, T2) showed no significant difference compared to the CK treatment.

In summary, under the experimental conditions, selenium fertilizer treatment had no significant effect on the brown rice rate of rice.

## Effects of selenium fertilizer application on the nutritional quality of rice

As shown in Fig. 4A, the protein content of Guiyg 9, Ge 68 Superior 9938, and Ye xiang YouLisi under T1 treatment was 4.95%, 5.45%, and 5.51%, respectively. Under T2 treatment, the protein contents of Guiyu 9, Ge 68 Superior 9938, and Yexiang You Lisi were 5.92%, 5.67%, and 6.15%, respectively. The protein content of all three rice varieties increased with rising selenium treatment concentrations. Fig. 4B shows that in the T1 treatment group, the amylose contents of Guiyu 9, Ge 68 Superior 9938, Yexiang Youlisi exhibited amylose contents of 16.71%, 23.0%, and 18.85%, respectively, all significantly higher than the CK. Except for Ge 68 Superior 9938, the amylose contents of the other two varieties met the national standard range for high-quality indica rice (13.0%–22.0%).

As shown in Fig. 4C, lipid content in all three varieties under T1 treatment showed no significant change compared to CK. However, lipid content in Guiyu 9, Ge 68 Superior 9938, and Yexiang YouLisi under T2 treatment was 1.09%, 1.83%, and 1.78%, respectively, all significantly higher than CK. As shown in Fig. 4D, selenium content in Guiyu 9 grains increased with higher selenium fertilizer concentrations. However, significant increases in selenium content for Ge 68 Superior 9938 and Yexiang YouLisi grains were only observed under T2 treatment.

In summary, under the T2 treatment, the protein content, amylose content, lipid content, and amino acid content of the three rice varieties reached their highest levels and were all significantly higher than the CK.

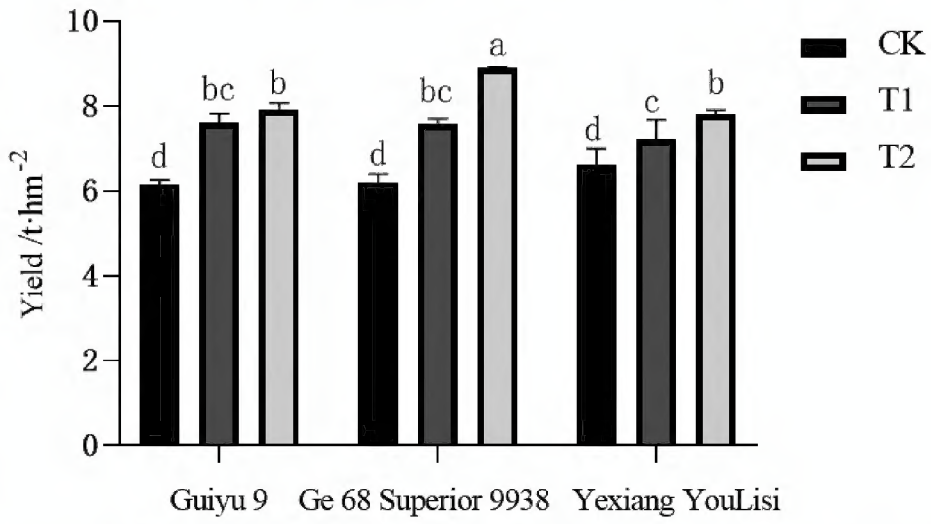


**Figure 4.** Nutritional quality of rice grains under different selenium treatments. Note: Different lowercase letters indicate significant differences among selenium treatments at $p < 0.05$.

## TOPSIS method for comprehensive evaluation

A comprehensive evaluation was conducted using the Entropy Weighted TOPSIS method, combined with measurement data, to select suitable rice varieties and selenium fertilizer application methods. Evaluation indicators and weights are presented in Table 1. Selenium content is an interval indicator (0.04–0.3 mg•kg$^{-1}$, Set PIS to 0.3; the closer the value is to the selenium content, the better the effect. Set NIS to 0.3; the closer the value is to 0.04, the poorer the selenium content effect.). Yield, brown rice rate, lipid content, protein content, and total essential amino acids are positive indicators, while amylose content and selenium fertilizer cost are negative indicators. Weights for each indicator were calculated after normalizing data using the sum of squares method.

Construct a weighted matrix and calculate the distance between each treatment's metrics and the positive and negative ideal solutions. Compute the relative proximity and rank the results, as shown in Table 2.

**Table 1.** Evaluation indicators and indicator weights.

| Evaluation indicators | Indicator type | Entropy value | Coefficient of variatione | Weight coefficient |
|---|---|---|---|---|
| Yield | Interval | 0.8518 | 0.1482 | 0.1181 |
| Brown rice ratio | Upward | 0.83683 | 0.16317 | 0.1300 |
| Grain Selenium content | Upward | 0.89921 | 0.10079 | 0.0803 |
| Amylose content | Downward | 0.9001 | 0.0999 | 0.0796 |
| Lipid content | Upward | 0.72442 | 0.27558 | 0.2197 |
| Protein | Upward | 0.90537 | 0.09463 | 0.0754 |
| Amion acids content | Upward | 0.83833 | 0.16167 | 0.1289 |
| Selenium fertilizer cost | Downward | 0.78969 | 0.21031 | 0.1676 |

**Table 2.** Composite score index and ranking of rice varieties and selenium treatments.

| Variety | Treatment | D+ Distance from positive ideal solution | D- Distance from negative ideal solution | Relative closeness coefficient | Ranking result |
|---|---|---|---|---|---|
| Guiyu 9 | CK | 0.31801 | 0.18615 | 0.36922 | 9 |
| | T1 | 0.24958 | 0.17239 | 0.40853 | 7 |
| | T2 | 0.26725 | 0.19819 | 0.42582 | 6 |
| Ge 68 Superior 9938 | CK | 0.29243 | 0.19549 | 0.40066 | 8 |
| | T1 | 0.25978 | 0.19386 | 0.42734 | 5 |
| | T2 | 0.20942 | 0.30144 | 0.59007 | 2 |
| Yexiang YouLisi | CK | 0.24709 | 0.22549 | 0.47715 | 3 |
| | T1 | 0.24923 | 0.1922 | 0.43541 | 4 |
| | T2 | 0.1881 | 0.27781 | 0.59628 | 1 |

It is evident that Yexiang You Lisi in T2 treatment exhibits the highest proximity to the ideal solution and ranks first. Under T2 treatment, each variety achieves a higher comprehensive evaluation score than T1 and CK, indicating that all three rice varieties demonstrate optimal performance across all comprehensive metrics under T2 treatment.

## Discussion

Results indicate that foliar application of selenium fertilizer significantly increases rice yield. Gao et al. (2024) research found that elevated selenium content in rice plants enhances yield, consistent with the findings of this study. With increasing fertilizer application rates, yields of Ge 68 Superior 9938 and Yexiang YouLisi varieties showed significant increases. However, the yield of Guiyu 9 did not show a significant increase with higher selenium fertilizer application rates. It is speculated that the optimal selenium fertilizer application rate for Guiyu 9 is 100 $g \cdot hm^{-2}$, which may be related to the characteristics of this specific variety.

Selenium treatment significantly increased selenium content in various parts of rice plants. As shown in Fig. 2A, B, under the T1 treatment, both stem and leaf selenium content in Guiyu 9 and Ge 68 Superior 9938 varieties were significantly higher than in the CK treatment. This indicates that applying selenium fertilizer at a rate of 100 $g \cdot hm^{-2}$ effectively increases selenium content in stems and leaves. For the Yexiang YouLisi variety, stem selenium content was significantly higher than CK only under the T2 treatment, indicating that selenium fertilizer concentrations must reach at least 200 $g \cdot hm^{-2}$ to increase stem selenium content in this cultivar.

However, the leaf selenium content of Yexiang YouLisi was significantly higher than CK at a selenium fertilizer concentration of 100 $g \cdot hm^{-2}$. This difference may stem from variations in selenium uptake and supply mechanisms across different plant parts within this cultivar, requiring further experimental investigation to elucidate the specific mechanisms involved. Results Fig. 2C, D indicate that selenium content in both ears and grains of Guiyu 9 and Ge 68 Superior 9938 significantly increased under T1 and T2 treatments. Moreover, as selenium treatment concentration rose, ear and grain selenium content also increased. This suggests a positive correlation between selenium fertilizer concentration and selenium content in ears and grains for these two varieties. For Yexiang YouLisi, ear stalk selenium content showed significant improvement only under T2 treatment, while grain selenium content increased significantly under T1 treatment alone. This indirectly reflects Yexiang YouLisi unique absorption and distribution patterns of selenium within the plant.

According to the Guangxi local standard"Classification Requirements for Selenium Content in Selenium-Enriched Agricultural Products"(DB 45/T 1061-2014) rice with selenium content ranging from 0.15 to 0.5 $mg \cdot kg^{-1}$ can be classified as selenium-enriched rice. In this study, all three rice varieties grown in selenium-enriched soil under the CK treatment exhibited grain selenium content below 0.15 $mg \cdot kg^{-1}$. However, under the T1 treatment, the grain selenium content of Guiyu 9, Ge 68 Superior 9938, and Yexiang YouLisi all exceeded 0.20 $mg \cdot kg^{-1}$, meeting the aforementioned selenium-enriched rice standard. This indicates that even when cultivated in selenium-enriched soil, rice requires exogenous selenium fertilizer application to achieve grain selenium levels meeting selenium-enriched rice requirements. Research findings from both Dun et al. (2025) and Gu et al. (2024) confirm that exogenous selenium fertilizer application enhances grain selenium content in rice.

Soil selenium content has reached the level of selenium-enriched soil, yet the correlation between soil available selenium and rice selenium content remains weak (Li et al. 2023; Liu et al. 2023). The native selenium in the soil may be predominantly present in non-bioavailable forms, such as insoluble elemental selenium or reduced selenides. In contrast, the foliar-applied fertilizer likely contains highly soluble and bioavailable forms (e.g., selenate or selenite), which bypass the soil system entirely and are readily absorbed by the leaves. This difference in chemical speciation is a major factor. The rice varieties used may exhibit poor root-to-shoot translocation efficiency for selenium absorbed from the soil. This suggests that even if some native Se is absorbed by the roots, the plants are inefficient at transporting it to the grains. The effectiveness of the foliar application confirms that bypassing root uptake is the most direct and efficient route for Se enrichment in the grains for these specific genotypes.

Further research reveals that the increase in grain selenium content is closely linked to selenium treatment regulation of rice photosynthetic capacity. Selenium treatment significantly enhances photosynthetic efficiency in leaves across all growth stages, providing ample nutrition for grain development. Additionally, selenium treatment significantly improves rice processing quality, enhances rice flavor, and ultimately results in higher taste and disintegration values for the rice (Gao et al. 2024; Hu et al. 2025; Wang et al. 2025).

The brown rice rate is a key indicator for assessing the processing quality of rice. Research has shown that brown rice preserves the nutritional value of rice grains more completely (Lv et al. 2020). As shown in Fig. 3, there were no significant differences in the brown rice rate among Guiyu 9, Ge 68 Superior 9938, and Yexiang YouLisi under the three treatments, indicating that selenium treatment had no apparent effect on the brown rice rate of these three varieties.

The content of amylose, lipids, proteins, and amino acids serves as core indicators for evaluating the nutritional quality of rice and is closely related to its cooking and eating quality (Weng et al. 2024). This study demonstrates that selenium treatment increases the content of proteins, lipids, amylose, and amino acids in rice grains. Specifically, under the T1 treatment, the protein and amylose contents of all three varieties significantly increased. Specifically, selenium treatment elevated protein content to 4.95%–6.15%. This indicates that appropriate selenium fertilization enhances rice grain protein content, thereby improving rice quality—a finding consistent with Zhang et al. (2014) and Shi et al. (2019). Furthermore, the study found that selenium fertilizer application not only increases rice yield, amino acid content, and amylose content but also significantly elevates grain soluble sugar content (Huang et al. 2024).

The comprehensive evaluation results using the TOPSIS method indicate that Yexiang Youlisu is the most suitable rice variety for cultivation in southern Guangxi. Under treatment T2, Yexiang Youlisu achieved the highest overall ranking in terms of yield and rice quality. To produce selenium-enriched rice in selenium-rich soil areas, it is essential to select appropriate rice varieties. Identifying suitable selenium-enriched rice varieties represents a crucial pathway for Guangxi to develop selenium-enriched agriculture.

## Conclusions

The results of this study indicate that applying selenium fertilizer to selenium-rich soil can increase rice yield, with the most pronounced effect observed in the Ge68 Superior 9938 variety. Selenium treatment had no significant impact on rice brown rice rate but significantly increased selenium content in rice stems, leaves, panicle stems, and grains. As selenium fertilizer concentration increased, grain selenium content also rose. Comprehensive evaluation using the TOPSIS method indicated that the Yexiang YouLisi variety demonstrated optimal cultivation performance in selenium-rich regions of Guangxi. When selenium fertilizer was applied at a concentration of 200 mg•hm$^{-2}$, this variety achieved the highest yield, best rice quality, and greatest economic benefits.

## Author contributions

Li Fuyan was responsible for drafting the initial manuscript and reviewing revisions, while Li Xuming handled experimental design, data collection, and analysis.

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